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What's Wanting to Happen

Strangely enough, some good literary and artistic friends of mine - spiritual friends, since most have departed the planet - have some things to say about mesh generation and CFD. So, being too far along now to have anything new to say about how to generate meshes and do CFD, I'll try to make some connections tonight between science and literature (and art) and, of course, mesh generation.

Beginnings

In a book called *Art and Physics: Parallel Visions in Space, Time & Light* by Leonard Shlain, I read that Newton made reference to "the glory of geometry". Newton was not satisfied with his formulations until he could make an easily visualizable geometrical model he could see. And Shakespeare spoke of imagination turning the forms of things unknown into shape and giving "airy nothing a habitation". Clearly, that "airy nothing" refers to meshless methods.

This book goes on to point out that the development of perspective in the 15th century was a revolutionary milestone in the history of art, suddenly opening the 2D canvas to the 3D world. Mesh generation analogously moved computational simulation from squares and circles into the real world. Renaissance parents urged their children to become professional perspectivists because the skill was in such demand. And, although I couldn't have expected at the outset to make my own career out of meshes, there has been some demand for a few of us such folks. But our measure of real success is actually in reducing that demand by automating the whole process.

The Bible makes reference in the creation account to the earth being without form and void – i.e., meshless. But the Creator wasn't satisfied, and went on to give form, and thus came mesh generation. The Bible also speaks of the "four corners of the earth" – surely that anticipates structured grids mapping the surface of a sphere to a cube. There's even early reference to adaptive meshing: recall the long-suffering Job being asked "Can you bind the chains of the Pleiades; can you loose the bonds of Orion?". And Shakespeare has King Lear pronounce, upon the unrolling of a map: "Strike flat the thick rotundity o' the world". Mapping was, in fact, a precursor to mesh generation, and cartography became a science in the 16th century as Gerardus Mercator squashed the spherical earth onto a flat piece of paper, providing sailors with a map on which they could plot fixed courses as straight lines.

Along with perspective, the 15th century also saw the use of shadow introduced into art by Piero della Francesca, further enhancing the 3D representation. Even

the idea of visualization via a 2D graph was once a major advance, introduced by Nichole d'Oresme, a medieval schoolman, in the 14th century. The ability to make abstract concepts visual was an absolute prerequisite for the scientific discoveries, and the engineering applications, that followed.

The Soft Side

Cezanne, who devoted his artistic career to a study of the relationship of space, light, and matter, had this to say, thinking undoubtedly of volume mesh generation and volume visualization:

> *Nature is more depth than surface, the colours are the expressions on the surface of this depth; they rise up from the roots of the world.*

John Russell in *The Meanings of Modern Art* makes the connection with scientific visualization:

> *Color is energy made visible.*

And Monet painted haystacks at various times of day to show the passage of time. Time is inexorably linked with music, and Stravinsky put it:

> *Music's exclusive function is to structure the flow of time and keep order in it.*

But mesh generation is about space more than time, and I relate to William Blake’s assertation that

> *Time is a Man, Space is a Woman.*

My point in all this is that art informs science, and Leonardo da Vinci, the quintessential artist/engineer, put it this way:

> *Art is the Queen of all the Sciences, communicating knowledge to all the generations of the world.*

Back in 1988, Joe Steger and I did an AGARD survey of structured grid generation in practice on large aerospace applications in Europe and the U.S. Joe departed the planet much too early, ten years ago now, but we had this to say in that AGARD report:

> *The problem of grid generation can still be as much an art form as it is a scientific discipline.*

That sentence was actually Joe's writing, not mine.

So Broader Horizons

And there’s also a relation with the broader humanities, literature as well as art. Back in 1995, William Wulf, now president of the National Academy of Engineering and one of the pioneers of IT research while at the National Science Foundation, said:

Humanists will lead the way to innovative applications of information technology in the university.

When asked late in his life to catalogue the most important influences upon his thinking, Einstein declared, "Dostoyevsky gave me more than any thinker, more than Gauss". Creativity is the hallmark of the engineer, and there is Einstein's famous quote, that seems to apply in particular to mesh generation:

Imagination is more important than knowledge.

W.H. Auden, in *Dyer's Hand*, refers only to scientists, but he clearly meant engineers even more so:

The true men of action in our time, those who transform the world, are not the politicians and statesmen, but the scientists. Unfortunately poetry cannot celebrate them, because their deeds are concerned with things, not person, and are, therefore, speechless.

But John Fowles has a geologist in *The French Lieutenant's Woman* say:

We all write poems; it is simply that poets are the ones who write in words.

Engineers (and scientists)

Technology enables new approaches and applications for the arts and humanities, but it goes both ways. A while ago there appeared in the personal column of the *New York Review of Books* an ad, which ran something like this:

Petite, attractive, intelligent WS/J 30, fond of music, theatre, books, travel, seeks warm, affectionate, fun-loving man to share life's pleasures with view to lasting relationship. Send photograph. Please no biochemists.

At least she didn't exclude engineers.

We read continually that fewer U.S. students are going into science and engineering. Yet we are becoming more and more dependent on technology in everything from the economy to defense to the quality of life. My fellow Mississippian, William Faulkner had a country man say, in "The Tall Men":

Life has done got cheap, and life ain't cheap. Life's a pretty darn valuable thing. I don't mean just getting along from one WPA relief check to the next one, but honor and pride and discipline that make a man worth preserving, make him of any value. That's what we got to learn again. Maybe it takes trouble, bad trouble, to teach it back to us.

Wulf again, this time on "The Image of Engineering" in the Winter 1998 *Issues in Science and Technology*:

What do engineers do?

My favorite quick definition of what engineers do is "design under constraint. "We design things to solve real problems, but not just any solution will do. Finding a solution that elegantly satisfies all these constraints is one of the most difficult and profoundly creative

activities I can imagine. This is work that in some ways has more in common with our artistic colleagues than our scientific ones.

Listen to Walt Whitman, "Singing the great achievements of today/Singing the strong light works of engineers."

Dewitt Jones, a *National Geographic* Photographer, once told me, talking about still looking for the great photograph after the good:

Look for what's wanting to happen.

But that's what engineers do. And the future depends on the breadth, as well as the depth, of our knowledge.

Approximation, Conservation and CFD

Aristotle, in *Nichomachian Ethics* spoke directly to engineering, and to mesh generation:

It is the mark of an educated mind to rest satisfied with the degree of precision that the nature of the subject admits, and not to seek exactness when only an approximation is possible.

One must always be ready to improvise, and to be alert to what is passing by. From Thomas Hardy:

It is safer to accept any chance that offers itself and extemporize a procedure to fit it, than to get a good plan matured, and wait for a chance of using it.

My own career developed from reading the right paper at the right time, and seeing a possibility that had not been appreciated. That was lucky, but as Pasteur said:

Luck favors the prepared mind.

Events have a way of finding leaders. Listen to Rainer Marie Rilke:

If I don't manage to fly, someone else will.
The spirit wants only that there be flying.
As for who happens to do it,
In that, he has only a passing interest.

One thing to remember in all of life is that the conservation laws are more fundamentally derived in integral form. The differential form only comes later after some assumptions of continuity are made. This has technical bearing on the question of meshless methods, since they are based on the differential form.

Emerson, in *On Experience*, put that this way:

The years teach much which the days never know.

And Dewitt Jones again, the *National Geographic* photographer:

Completeness, not flawlessness, is what is important.

There are some obvious references to CFD in literature. Thus the *Irish Blessing*:

> *May the road rise up to meet you.*
> *May the wind be always at your back.*

Clearly this refers to upwind differencing.

The Navajos even knew about central differencing and iterative methods; thus in *Nightway Chant*:

> *With Harmony may I walk,*
> *With Harmony behind me, may I walk,*
> *With Harmony above me, may I walk,*
> *With Harmony below me, may I walk,*
> *With Harmony all around me, may I walk.*
> *It is finished in Harmony.*

Making Entropy

Science also informs the humanities, and the Second Law of Thermodynamics is an absolute must for any complete education, not just for scientists and engineers. It is really rather discouraging, since it basically says that everything is constantly proceeding to a state of greater disorder. It means things eventually become so completely random that everything is the same, and therefore nothing happens anymore. It means that all the order we achieve is merely a perturbation, which is unstable and will be ground down. Handel incorporated the Second Law in a tenor solo in *Messiah*. Remember the lines, from *Isaiah*:

> *Every valley shall be exalted, every mountain and hill made low, the crooked straight and the rough places plane.*

The Second Law of Thermo says that disorder is the norm. One of Hardy's characters in *Far from the Madding Crowd* says:

> *Wet weather is the narrative, and fine days are the episodes, of our country's history.*

So ever upward goes the entropy. Matthew Arnold said, of us engineers, I suppose:

> *Nature, with equal mind,*
> *Sees all her sons at play;*
> *Sees man control the wind.*
> *The wind sweep man away.*

The point of the Second Law is that one always has to make positive effort to achieve order. The default is clearly disorder.

The Internet is the greatest entropy generator yet devised - allowing everyone with nothing to say to say it to everyone. Civilization may end in valueless uniformity - will just stop - rather than in a cataclysm. I am really coming to believe that although inventiveness always increases, feeding on itself, I'm afraid imagination and creativity do not.

The Precautionary Principle

There was an article in the December 2000 *Scientific American* entitled "The New Uncertainty Principle" that speaks of the "precautionary principle", whereby the effect of new technology on the environment is considered along with the desire for advancement, as a moderator on speed of application. The concern stated was in regard to the physical environment, but such concern may well be applied also to the effect of information technology on the human operational environment. PITAC, on which I was privileged to serve in both the Clinton and Bush administrations, called for research into the socio-economic aspects of information technology - the impact of IT on the human environment, noting:

> *It is often the case that the implementation of information technologies has a considerably different set of consequences than were originally intended or anticipated.*

An article entitled "Are We Forgetting the Risks of Information Technology" in the December 2000 issue of *IEEE Computer* enunciated similar concern, noting adverse national impacts from our rapidly increasing reliance on IT and the Internet, including decreasing response time. This article went on to express concern that new IT is used immediately after it is introduced, with risk analysis to come later, and puts it bluntly:

> *The adage that there is no free lunch seems to have escaped our society when it comes to advanced IT use. We continue to accept the economic and other myriad benefits of IT without simultaneously conducting an appropriate, comprehensive cost-risk-benefit analysis. This constitutes a major societal failure.*

The article closes with the admonition:

> *If we don't begin to answer these questions in a systematic and meaningful way, we will reap the whirlwind of technology that has become indispensable but whose reliability and trustworthiness have become questionable.*

The wild ride with IT in the 90s recalls Faulkner's mule:

> *A mule will work for a man faithfully for ten years – for the pleasure of kicking him once.*

Faulkner said that in reference to the Mississippi River flood of 1927, but it applies now also. But I'm delighted to see that the mesh generation companies that flowered in the 90s are still around, in contrast to all the long-gone dot-coms based on selling cat food on the Internet.

Automation & Creativity

So now we have computational simulation - the third paradigm of scientific investigation - potentially much more far-reaching that the first two paradigms. Both experiment and theory are inherently limited: experiment by the practical impossibility of testing all possibilities, and theory by the practical inability to solve the equations. But the computational mode is unlimited: only more powerful machines and algorithms are necessary, in principle, to include

all possibilities and to achieve any accuracy. And the third mode enables optimization.

This is both exciting and disturbing. Complete automation of the design cycle - and mesh generation - would allow total customization and optimization, opening the possibility of an infinite variety of products to meet all human needs: and eliminating the need for us engineers in the process. So we come to the stage of having all human desires satisfied with no human involvement: not an entirely comfortable feeling - are we then masters, or slaves to cold logic? Software is logical creativity, and the essence of engineering is creativity, but can we come to be so effectively creative as to no longer require creativity, or to be allowed to exercise it, assuming we even survive the effects of all our creativity? I continue to be perplexed by the computer virus phenomenon. I don't think there's a comparable instance in another technology of creativity run amuck.

Unrelenting Change

Ted Lewis, writing in the September 1995 issue of *IEEE Computer* - "Living in Real Time" said:

> *Civilization is reaching a terminal velocity - a rate of change so voracious that it is limited by the human capacity to absorb it. The major characteristic of living in the Info Age is constant, unrelenting, maximum change.*

Life is change, though, and remember what the condition for Goethe's Faust to lose his soul was - that he could be led to a situation so pleasant as to say *Verweile doch, Du bist so schon* - that is to a condition that he never wanted to change. By the way, Goethe spent ten years studying botany, zoology, geology, and meteorology.

Newton's First Law of Motion says that things at rest tend to stay at rest and things in motion tend to stay in motion. We call it inertia. Here's Faulkner's expression of the First Law, from *Light in August*:

> *It is because a fellow is more afraid of the trouble he might have than he ever is of the trouble he's already got. He'll cling to the trouble he's used to before he'll risk a change.*

I have that one on my wall, and I've included it in a lot of technical presentations over the years. We have to welcome change, but we also have to control it - assuming that is still possible.

So Life

Life is precious and the days go quickly. The English playwright, George Bernard Shaw, put it thus:

> *I want to be thoroughly used up when I die, for the harder I work the more I live. I rejoice in life for its own sake. Life is no brief candle to me. It is a sort of splendid torch that I have got hold of for the moment, and I want to make it burn as brightly as possible before handing it on to future generations.*

But it’s hard not to like Edna St Vincent Millay’s *First Fig*:

> *My candle burns at both ends;*
> *It will not last the night;*
> *But ah, my foes, and oh, my friends –*
> *It gives a lovely light!*

Finally, in Faulkner's *Big Woods*:

> *Think of all that has happened here, on this earth. All the blood hot and strong for living, pleasuring, that has soaked back into it. For grieving and suffering too, of course, but still getting something out of it for all that, getting a lot out of it, because after all you do not have to continue to bear what you believe is suffering; you can always choose to stop that, put an end to that. And even suffering and grieving is better than nothing; there is only one thing worse than not being alive, and that's shame. But you can't be alive forever and you always wear out life long before you have exhausted the possibilities of living.*

I have that one on my wall also.